TECHNICAL FEATURE SECTION

The Journal OF THE AMERICAN SOCIETY OF SAFETY ENGINEERS

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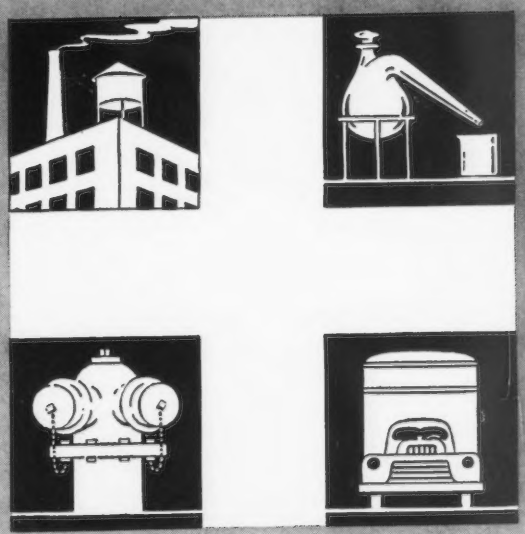

AUGUST, 1958

Quo Vadis?

THE safety movement today is faced with a number of problems. Some of these problems—or challenges, as they properly may be called—have been outlined in articles and editorials in previous issues of the Journal. And on page 45 of this issue, Professor Thomas Rockwell of Ohio State University points out our vital need for extensive, coordinated research on the fundamental causes of accidents.

Perhaps our most basic need, however, is for a definition of the true nature of professional safety work in the modern industrial world, as is so ably discussed by Society President John Juli in his editorial on page 33.

The Society has taken the first step in arriving at such a definition by initiating its current study on the organizational position of the industrial safety engineer. Questionnaires have been printed which, when completed and tabulated, will give us the facts in many important areas where heretofore we have had little knowledge and many controversial opinions.

These questionnaires were mailed to all Society members approximately two weeks ago. Already some members have completed and returned their copies, an indication that there is a realization by the membership of the significant nature of this undertaking.

We want to urge every Society member to fill in his questionnaire carefully and fully and return it to national headquarters as soon as possible, so that our study can be completed without delay.

It is only by knowing, authoritatively, where our profession stands today that we can intelligently plan our course for the future. And, with the rapid growth which the Society recently has experienced, it daily becomes more urgent that we reach some firm decisions on the direction in which the Society should travel, and why.—Editor

AMERICAN SOCIETY OF SAFETY ENGINEERS

Organized 1911 — Chartered 1915

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This Journal section is the official technical publication of the American Society of Safety Engineers. It will appear quarterly in the National Safety News as a service to the Society by the National Safety Council. Separately bound copies of this section for exchange purposes are provided the Society by the Council.

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OUR PRESIDENT SPEAKS ON SAFETY

FOR some 40 years many of us have been calling ourselves safety engineers and have been looking upon our profession as one of the branches of engineering. Perhaps this attitude has been proper and correct. Certainly in the early years of the safety movement, major emphasis necessarily was on machine guarding and arrangement of the physical plant. We still must be concerned with problems of engineering for safety, of course. And we cannot and should not discard lightly the tradition-backed concept of our profession.

However, in recent years many of our number have seriously and sincerely questioned whether it is either appropriate or wise for us to "hitch our wagon," professionally speaking, to engineering.

These men, many of them graduate engineers, point out that, as to the amount of time now spent on engineering by those who are employed full time in safety, responsible estimates range from 5 to 40 per cent. Even acceptance of the 40 per cent figure, they say, can not place the safety man on a par, as an engineer, with the average member of a founder engineering society, who devotes perhaps 80 to 95 per cent of his work day to engineering. Thus, it is reasoned, the safety profession is not likely ever to achieve a top position in the engineering ranks.

On the other hand, it is said, safety actually is a unique, independent profession; successful safety practice requires knowledge and ability of unusual breadth, embracing engineering and, in general, such fields as education, statistics, industrial medicine, salesmanship, personnel administration, law and psychology, to name a few.

A college graduate entering safety work can be expected to have academic training in only one or two, of course; the others he must learn later, through experience and postgraduate classes. Which of the applicable fields he studies as an undergraduate is not very important, many believe.

Industry, in selecting safety men today, apparently agrees. At least, this seems to be indicated by the fact that, of the 400 most recent admissions to Society membership, only about 10 per cent hold engineering degrees.

Even more significant to our profession, however, is the fact that a substantial majority of these new members are not college graduates. One possible conclusion that can be drawn from this: we have been so insistent on recognition of safety as an *engineering* profession that, in failing to sell this idea effectively, we have by default left management with no clear conviction that safety is a *profession* and requires of its young recruits, generally, a level of education which gives some assurance of ability to understand and meet the complex demands of the job.

Our relatively young profession is growing rapidly toward maturity; the moment of decision has arrived when we must determine the character of that maturity. We must define, clearly and accurately, the areas of knowledge and standards of performance which give us a legitimate claim, before management and the world, as specialists of professional standing. And first of all, we must reach agreement on the basic nature of our work.

JOHN F. JULI, PRESIDENT
AMERICAN SOCIETY OF SAFETY ENGINEERS

IMPACT TEST ON GLASS

BY C. A. PIPPIN

C. A. Pippin is in charge of the Mechanical Laboratory at Dow Chemical Company's Rocky Flats Plant in Denver, Colorado. He holds a bachelor of science degree from the University of Illinois and a master's degree from Kansas State College, where he taught mechanical engineering for five years before he became associated with Dow in 1942.

Introduction

AFTER a recent accident involving a wired glass window in a door (at the Rocky Flats Plant, Dow Chemical Company, Denver, Colorado), it was decided to obtain impact data on the various types of glass. The Safety Department attempted to get this information from various sources, including the glass manufacturers, but the information does not appear to be available. A committee, formed to determine actions to be taken as a result of the accident, requested the Mechanical Laboratory to make impact tests on the various glasses. A glass size of 18 inches by 24 inches was chosen for use in the tests.

Summary

Plastic sheets of acrylic resin* withstood the greatest impact, but were subject to being easily scratched. Next strongest were tempered glass and allyl ester plastic sheets,* with tempered glass being slightly stronger. Laminated and wired glass had essentially the same impact strength. Double strength glass was very weak, but the thickness was only ⅛ inch. All of the impact strengths listed in Table I were obtained using a 6.685 pound felt-covered ball.

Procedure

The general procedure used in testing glass was that of fastening a piece of the glass (18 inches by 24 inches) into a wooden frame similar to a door and then dropping a felt-covered wooden ball upon the center of the glass from various heights until the glass broke.

In order to maintain uniform conditions, the frame was set on 1 inch foam rubber. This was done to eliminate the effect of the frame being unevenly supported on a concrete floor. Most of the work was done with a felt-covered wooden ball having an apparent density of 0.838 gm/cc. The center of this ball was steel. Actually, there were three balls available for the test. Each of these balls had the same outside dimensions but each had different-sized steel cores so as to give different apparent densities. Only two of the balls were used in these tests.

The wooden ball had an "eye" screwed into it. A piece of string was looped through the "eye" and the ball was held over the glass by means of a hoist. After obtaining the desired distance from the ball to the glass, the string was cut. The distance was increased until the glass failed.

Discussion

For the maximum in safety, the acrylic resin plastic sheet showed up much better than any other "glass" tested. It tested approximately twice as good

TABLE I—Cost and Impact Strength Data

	Average Impact Strength Pounds-Inches	Approximate Cost per Square Foot
Double strength (⅛ in.)	25	$ .55
Laminated (¼ in.)	110	.80
Plate glass (¼ in.)	110	1.25
Wired glass (¼ in.)	112	1.02
Allyl ester plastic (¼ in.)	555	4.62
Tempered glass (¼ in.)	582	2.60
Acrylic resin plastic (¼ in.)	1,086	1.49

Many types of plastic sheets, of similar and varying characteristics, are being manufactured today under various trade names. The acrylic resin plastic sheets used in these tests were Plexiglas. The allyl ester plastic sheets used were Homalite.

TABLE II—Glass Test Data

Type	W (lb)	Drop (in.)	Wd (in.-lb)	$\overline{R}$	$\overline{X}$
Double strength	6.685	3	20.06		
Double strength	6.685	5.75	38.44		
Double strength	6.685	4	26.74		
Double strength	6.685	2	13.37	25.07	24.65
⅛ in. acrylic resin plastic	6.685	98	716.66		
⅛ in. acrylic resin plastic	6.685	98	716.66		716.66
⅛ in. acrylic resin plastic	8.975	70	628.25		
⅛ in. acrylic resin plastic	8.975	74.5	668.64		
⅛ in. acrylic resin plastic	8.975	110	987.25		
⅛ in. acrylic resin plastic	8.975	70	628.25	359.00	728.14
¼ in. acrylic resin plastic	6.685	148	989.38		
¼ in. acrylic resin plastic	6.685	168	1123.08		
¼ in. acrylic resin plastic	6.685	152	1016.12	227.29	1086.31
*¼ in. acrylic resin plastic	6.685	182	1216.67	(no failure)	
*¼ in. acrylic resin plastic	8.975	134	1202.65		
Wired glass	6.685	16	106.96		
Wired glass	6.685	16	106.96		
Wired glass	6.685	23	153.76		
Wired glass	6.685	12	80.22	73.54	111.97
Laminated	6.685	18	120.33		
Laminated	6.685	12	80.22		
Laminated	6.685	18	120.33		
Laminated	6.685	18	120.33	40.11	110.30
Plate glass	6.685	14	93.6		
Plate glass	6.685	19	127.0		
Plate glass	6.685	13	86.9		
Plate glass	6.685	20	133.7	46.8	110.3
Tempered	6.685	116	775.4		
Tempered	6.685	84	561.5		
Tempered	6.685	96	641.7		
Tempered	6.685	52	347.6	427.8	581.55
Tempered	8.975	44	394.9		
Tempered	8.975	54	484.7	89.8	439.8
Allyl ester plastic	6.685	96	641.76		
Allyl ester plastic	6.685	70	467.95	173.81	554.85

Note: W (lb) = *Weight of felt-covered ball approximately 7½ inches in diameter.*

Wd (in.-lb) = *Weight in pounds times distance dropped in inches.*

$\overline{R}$ = *Range in inch-pounds between lowest and highest drop.*

$\overline{X}$ = *Average W x d of all samples tested in each test group.*

**Acrylic resin plastic sheet did not break at maximum height with 6.685 pound ball. Continued test on same specimen using 8.975 pound ball.*

in impact strength as its nearest competitor, tempered glass. Also, its cost was only about 60 per cent as much as tempered glass. The main disadvantage to the acrylic resin plastic seemed to be its poor resistance to scratching.

The allyl ester plastic sheet and tempered glass were about equal in impact strength but the allyl ester plastic was much more expensive than tempered glass. When the tempered glass broke, it broke into very small pieces and the pieces were not sharp.

Laminated and wired glass had about the same strength. The laminated glass had a slight cost advantage over the wired glass. In both cases, some of the broken pieces came off but the glass stayed together very well. The only pieces which came off were very small. Force applied was sufficient only to just break the glass. Behavior under excess impact was not studied.

The double strength glass test showed it to be very weak. Apparently, it should not be used if strength is a major requirement. However, it should be pointed out that the double strength glass was only about ⅛ inch, compared with a ¼ inch thickness for the other materials tested.

It will be noted that the heavy ball was used a few times; however, the only data used for comparison purposes were those obtained using the small ball.

FIGURE 1

Figure 1. Test procedure.

Figure 2. Acrylic resin plastic sheet fracture. The pieces were large and the edges were not very sharp.

Figure 3. Wired glass fracture. The pieces were held together by the wires.

Figure 4. Laminated glass fracture. The pieces were held together by the sheet of plastic.

Figure 5. Tempered glass fracture. The strength of this glass was next to acrylic resin plastic. The glass was completely reduced into very small but not sharp pieces.

FIGURE 2

FIGURE 3

FIGURE 4

FIGURE 5

safety in handling, storing and using LP gas

by Grover W. Ponton

TO THE person having only a casual acquaintance with liquefied petroleum gas, it may come as something of a surprise to discover just how extensively the gas is used. Often LP gas is thought of only as a cooking fuel, to be found mainly in rural areas. Actually, in addition to widespread domestic application, this product is being used with increasing frequency in a great variety of industrial and business operations.

The purpose of this article is to give the reader basic information on the fire and explosion hazards of LP gas and some of the control measures. Volumes could be, indeed have been, written about LP gas. This discussion will be confined to a general coverage of extent of use, physical characteristics, principles for control of hazards, portable cylinder storage, stationary storage, methods of transporting, use as a motor fuel, safety training of employes, emergency fire control. Also, final sections of the article list pertinent standards and codes and other literature helpful to the safety engineer dealing with problems involving LP gas.

Extent of Use

There are approximately 11.3 million users of LP gas, and 6.9 billion gallons of gas are stored, transported and used in a year. One of the most interesting aspects of the LP gas industry is that it is product of our times. It is a young industry which has developed in the last 30 years. For 1930, sales of LP gas totaled 18,017,000 gallons but, for 1957, sales were approximately 6,932,500,000 gallons, an increase of 384 times. The Liquefied Petroleum Gas Association in its January, 1958, issue of LP Gas Times estimated 1957 usage as follows:

	Gallons	*%*
Total Sales	6,932,500,000	
Domestic and Commercial	3,155,250,000	45.5
Chemical	1,569,000,000	22.6
Motor Fuel	856,750,000	12.4
Industrial	517,000,000	7.5
Synthetic Rubber	412,000,000	6.0
Gas Manufacturing	207,000,000	3.0
All Other	204,500,000	3.0

There are many different uses for LP gas in various occupations and businesses. Some of these are:

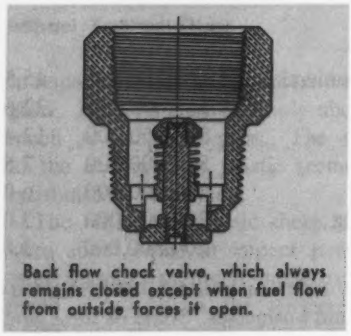
- Heating systems
- Cooking systems
- Cutting torches
- Melting pots
- Soldering irons
- Water heaters
- Glue pots
- Salamanders
- Steamers
- Smoke houses
- Brooders
- Raw material and solvent in chemical industry
- Automobiles
- Trucks
- Tractors
- Buses
- Industrial lift trucks
- Air conditioning
- Refrigeration
- Dryers
- Kilns
- Incinerators
- Weed burning
- Tempering equipment
- Internal combustion engines
- Manufacture of synthetic rubber
- Production of aviation gasoline and automotive fuel in refineries

Physical Characteristics

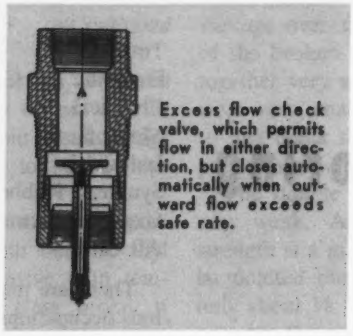
LP gas has many favorable characteristics which make it an excellent fuel. It is colorless and odorless in its natural state. It is a clean gas containing few impurities. Its cost is generally reasonable and, because of its ability to be liquefied, it is readily available at almost all locations.

Liquefied petroleum gas is a term applied to any flammable petroleum gas which at ordinary temperature is a gas but which, under moderate pressure, can be kept in liquid form. LP gas is a member of the hydrocarbon family of chemicals lying between natural gas and gasoline. Propane, butane and isobutane, or mixtures of these three gases, are the principal gases with which we are concerned in this group.

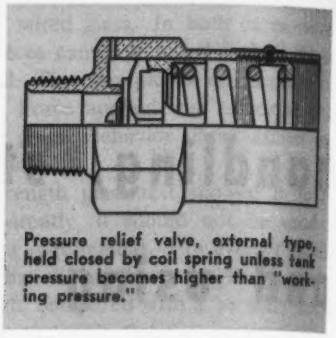
Grover W. Ponton is loss prevention specialist for Hardware Mutuals, Stevens Point, Wisconsin, where he has been employed since 1949. He holds two B.S. degrees, one in physical sciences from the University of Illinois and one in fire protection engineering from Illinois Institute of Technology. He joined the Society in 1951.



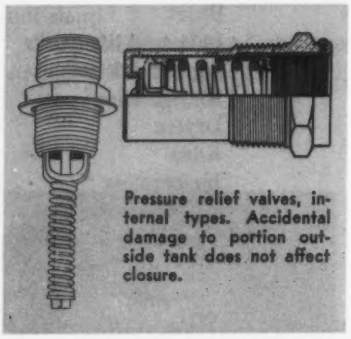
Back flow check valve, which always remains closed except when fuel flow from outside forces it open.



Excess flow check valve, which permits flow in either direction, but closes automatically when outward flow exceeds safe rate.



Pressure relief valve, external type, held closed by coil spring unless tank pressure becomes higher than "working pressure."



Pressure relief valves, internal types. Accidental damage to portion outside tank does not affect closure.

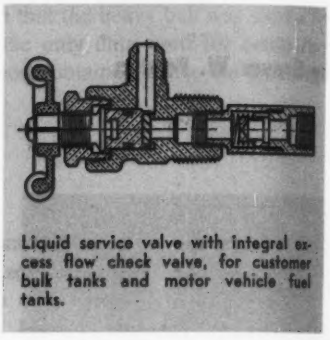
FUNDAMENTAL

VALVES AND FITTINGS

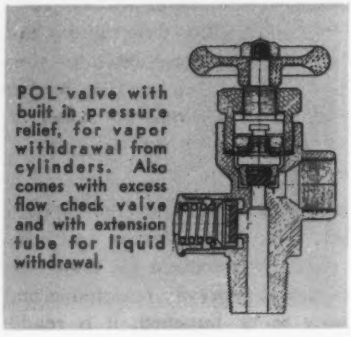
WHICH

MAKE TANKS

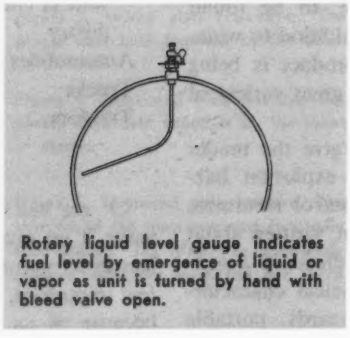
SAFE



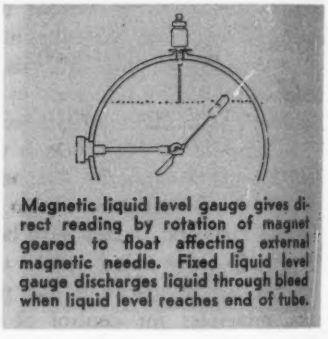
Liquid service valve with integral excess flow check valve, for customer bulk tanks and motor vehicle fuel tanks.



POL valve with built in pressure relief, for vapor withdrawal from cylinders. Also comes with excess flow check valve and with extension tube for liquid withdrawal.



Rotary liquid level gauge indicates fuel level by emergence of liquid or vapor as unit is turned by hand with bleed valve open.



Magnetic liquid level gauge gives direct reading by rotation of magnet geared to float affecting external magnetic needle. Fixed liquid level gauge discharges liquid through bleed when liquid level reaches end of tube.

Safety in LP Gas *Continued*

Some of the physical characteristics are:

	Propane $C_3 H_8$	Butane $C_4 H_{10}$	Isobutane $C_4 H_{10}$
Boiling point ° F	-44	32	10
Sp gr of gas (air = 1.00)	1.53	2.00	2.06
Vapor pressure lb/sq in. gauge			
60 F	92	12	24
100 F	172	38	59
Btu/gal liq at 60 F	91690	103500	100500
Limit of flammability			
Lower	2.3	1.9	1:9
Upper	9.5	8.4	8.4
Lb/gal liq at 60 F	4.23	4.85	4.71

(Note: Above data is from The LP-Gas Man's Encyclopedia of Methods and Equipment.[18]*)*

The hazard associated with LP gas arises from three basic facts:

1. The gas forms an explosive mixture in air.
2. It is a gas that is kept under pressure at ordinary temperatures.
3. It is heavier than air and will flow along the surface.

In preventing accidents in connection with LP gas, the above factors must be kept continually in mind. Practically all safety measures are developed as a control of these three physical characteristics.

Principles for Control of Hazards

The following are some general principles for the control of LP gas hazards:

(Note: These are general principles only. To determine what controls must be exercised in a specific case, reference should be made to the

accepted standards for LP gas. There are a number of variations, depending on container construction, size, location, use of gas, etc.)

1. As with all flammable materials, it is essential to keep possible sources of ignition away from the gas. This is accomplished by eliminating ignition sources and providing explosion proof electrical fixtures in all areas where free gas is likely to escape, such as during transfer operations and in storage areas.

2. LP gas, to be confined as a liquid, must be kept under pressure. As a result, it must be confined in containers, piping and equipment constructed to withstand the pressure. An excellent job has been done in designing and constructing mechanical equipment to contain LP gas.

All containers for LP gas must be designed, constructed and tested in accordance with specifications of the Interstate Commerce Commission,[16] with the API-ASME *Code for Unfired Pressure Vessels for Petroleum Liquids and Gases*[3] or with "Rules for Construction of Unfired Pressure Vessels," Section VIII, *ASME Boiler and Pressure Vessel Code*.[14] Equipment such as container valves, connectors, manifold valve assemblies, regulators, excess flow valves, gauging devices and relief valves installed on containers must be correct in design, construction and performance as determined by Underwriters' Laboratories, a recognized testing laboratory or an authority having jurisdiction. These provisions give assurance that the containers and equipment exposed to pressure will be strong enough to contain the gas under pressure.

All container valves and accessories must have a rated working pressure of at least 250 psig and be of suitable material for LP gas service.

3. LP gas in its natural state is odorless and colorless. As a leak cannot be detected visually, it must be odorized by an agent that will give a positive and distinct odor showing the presence of gas down to a concentration in air of not more than one-fifth the lower limit of flammability. Odorizing agents used are ethyl mercaptan, thiophane or amyl mercaptan.

4. Liquefied petroleum gas containers must be filled only partially. Space must be allowed in the container for expansion of the liquid with an increase in temperature. For instance, aboveground containers up to 1200 gallons capacity, containing propane with a specific gravity of 0.51, have a maximum liquid volume of 80 per cent.

In order that cylinders are not overfilled, those with less than 200 pounds water capacity are filled to a prescribed weight which allows sufficient vapor space for expansion. Other containers are provided with liquid level gauging devices.

5. Containers should be equipped with safety relief valves to release excessive pressure that may develop in a container. Excessive pressure may result from overfilling or exposure to excessive heat such as a fire. The safety relief valve allows the pressure to be relieved without rupturing the cylinder. Safety relief valves also should be provided between shutoff valves on piping where liquid is likely to be captured and excessive pressure occur.

6. Containers should be located outside of a building unless the building is especially designed for the purpose. This is to provide adequate ventilation for dispersion of gas that may occur around the cylinders. Every time a connection is broken, a small amount of gas escapes. In addition, this allows for dispersion of gas in case the relief valve operates.

For similar reasons, containers should be located at specified distances from building openings, buildings and adjoining property lines. Distance depends on size of tank and usage.

7. In case of breakage of piping, there should be some method to stop the flow of the gas in the container. Therefore, all connections to containers, except safety relief valves, should be equipped with shutoff valves, excess flow valve, or back pressure check valves, depending on type of connection and container.

8. One of the times when an accident is most likely to occur is during transfer of liquid. Therefore, a qualified employe should be in attendance during transfer operations to shut down the operation in case something goes wrong.

From the start, the LP gas industry has recognized the importance of safety and, considering the tremendous amount of exposure, has done an excellent job of preventing accidents. This does not mean that accidents do not occur. They do happen and some have been catastrophic. As is true in so many areas of accident prevention, the problem is people. Unsafe acts account for a very high percentage of the accidents which occur.

The material immediately following is a brief discussion of some areas of interest in storing, handling and using LP gas. While the general principles of control apply to all of these areas, each area has specific items of interest.

Portable Cylinder Storage

LP gas storage can be divided into two categories, portable cylinders and stationary storage containers.

Propane gas tank truck shows valve and hose enclosure. Openings to tank are protected by excess flow valves in case piping or connection is broken.

Safety in LP Gas *Continued*

Portable cylinders most commonly in use are 20 and 100 pound containers, although there is a large variety of other sizes available. These cylinders usually are filled at a bulk plant by weight and are delivered by truck to the user, although the cylinders can be filled on the premises of the user (if equipped with proper valves and gauges).

Portable cylinders frequently are referred to as "bottled gas systems" and utilize cylinders constructed in accordance with ICC specifications. The principle hazards associated with these containers are filling, transporting and storing.

Portable containers are constructed to withstand considerable abuse, as it is expected that they will be transported, for the most part, in trucks. These containers should be equipped with safety relief valves to relieve excess pressure that may occur.

If these containers were stored inside of buildings (other than buildings designed for such storage) and a leak occurred or the safety relief operated, it is very possible the gas would find a source of ignition and subsequently set fire to the building. Therefore, it is recommended that these containers be stored outside of buildings and away from building openings where the gas might gain entrance and reach a source of ignition.

This may raise the question about bringing portable cylinders into buildings for plumbers' torches or other industrial, construction and repair uses. An exception is made for such cases. Cylinders of less than 300 pounds capacity, while they never should be stored in buildings, may be used inside industrial buildings for processing or repair work or for construction, repair or improvement of buildings, structures, fixtures and equipment.

Indoors, cylinders should be located so that they are not subject to excessive rise in temperature, physical damage or tampering by unauthorized persons. All such containers should be removed from the building when not being used and at the close of the work day. If it is desirable to store such cylinders under cover, separate buildings should be constructed for that purpose.

Exceptions also are made for temporary use, indoors, of containers with a maximum water capacity of 12 pounds for demonstration purposes and of selfcontained gas hand torches with a maximum water capacity of 2½ pounds. Special exceptions also are applicable to storage of less than 2,000 cubic feet gas capacity on the premises of industrial users.

Although a container may be considered empty for use, it may have gas in it. Therefore, all valves should be closed even though the cylinder is considered empty and removed from service.

Cylinders having valve protecting caps should have these caps in place, when the containers are not connected for use, to protect valves from mechanical injury. The importance of protective caps for valves is illustrated by an incident in California. A man brought in a small portable tank to be filled with LP gas. The dealer objected to filling it because it did not have a protective valve cap; however, he did. The tank was placed in the car trunk. After traveling only a few blocks, the driver lit a cigaret and an explosion occurred. Apparently when the small tank rolled around in the trunk, the shut-off valve became loose and released gas.

Stationary Storage

Stationary storage tanks other than ICC cylinders are constructed in accordance with the API-ASME Code or the ASME Code. These tanks generally are used for the storage of LP gas in quantities larger than that in the commonly available ICC cylinders. Stationary tanks generally are used for storage on the premises of the user and for bulk storage at bulk LP gas plants and utility plants.

These tanks usually are filled on the premises of the user from tank trucks or railroad tank cars. The smaller installations have 500 or 1,000 gallon containers. A common large size storage container in use contains 30,000 gallons.

The problem with these stationary installations is the large quantity of gas involved. If this gas should escape, a very serious condition would exist. There is an additional problem in transferring gas from the storage tank to other containers or to points of utilization.

The tanks should be located so that they will not be subject to mechanical injury or to possible fires which might occur in nearby buildings. It would be very difficult to locate these tanks so that, in the event of total loss of gas, it would not flow into an area and cause an explosion. However, standard distance requirements for location attempt to be

practical as to distance. Thirty thousand gallon tanks should be placed at a minimum distance of 50 feet from important buildings or from lines of adjoining property on which buildings may be constructed. Such tanks should be protected from unauthorized tampering by a "man proof" fence. The tank should be securely mounted on solid masonry supports. Piping should be of adequate size to carry the maximum load and it should be protected from mechanical injury.

The farther high-pressure gas is transported in pipes, the greater is the exposure. Therefore it is desirable, wherever possible, to reduce pressure in piping by means of a pressure regulator at the tank.

The danger of transfer operations is illustrated by what probably was one of the worst accidents which has occurred in the industrial use of LP gas. In Minnesota, an explosion of butane vapors in the basement of a six story building killed 14 employes and seriously damaged the structure. Because of a railroad strike, a temporary unloading connection was used for tank truck delivery. This connection was an air line which was used in cold weather to supply air pressure for transfer of liquid butane to the vaporizers. It was possible for the liquid to flow back through the air line to the building where an open drain valve, on a water condensate leg in the air line, allowed gas to enter the basement.

It is advisable to have all valves and piping marked. Written instructions should be posted for each operation. In addition, employes should be thoroughly familiar with piping, valves and transfer procedures.

In filling tanks, special attention should be paid to whether the tank is constructed to withstand the vapor pressure of the gas it is intended to contain. Tanks constructed specifically for butane are not suitable for propane storage.

Methods of Transporting

There are four methods of transporting LP gas—by truck, rail, ship and pipeline. The two methods most frequently encountered are transportation by (1) truck in "bottled gas" cylinders or tank trucks and (2) railroad tank cars. Where applicable, LP gas transportation is subject to ICC regulations.

Truck transportation presents considerable hazard, not so much from the commodity being transported but from the general serious traffic safety problem. If a traffic accident should occur, the LP gas might compound seriously the consequences of the accident. However, in many traffic accidents that have occurred, the LP gas has been contained in its container.

In tank trucks, as with stationary storage of the gas, the containers are strongly constructed and valves are arranged to prevent the release of gas if piping should break.

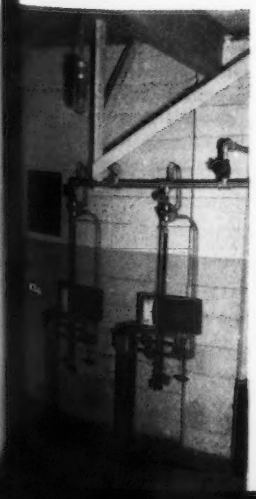
The possibility of accident can be reduced by following safe practices such as the following:

1. First, the driver must be selected and trained to drive safely. All operators should conduct a continuous fleet safety program.
2. The vehicle should be maintained in first class condition. The driver should report all conditions that need maintenance.
3. The vehicle and equipment should be thoroughly checked before being taken out.
4. Portable cylinders, when being transported, should be carried in an upright position and should be securely anchored to the vehicle.
5. The driver should not fill any illegal or potentially dangerous installations.
6. If it becomes necessary to shut down the gas supply in exchanging cylinders or refilling, all supplies of gas in the building should be checked before turning on the gas again.
7. Truck wheels should be blocked by chock blocks when filling tanks.
8. Drivers should be present and observe bulk delivery operations.
9. Care should be exercised to see that tanks are not overfilled.

Use as a Motor Fuel

LP gas as a motor fuel is relatively new and presents some interesting aspects. It is used for fuel on all types of motor vehicles: cars, buses, trucks, tractors and industrial lift trucks. A vehicle manufactured for use with LP gas, or converted properly, will operate efficiently and economically.

The basic hazard exposure here is similar to other LP gas operations; that is, safety requires storage in the proper container with suitable valves, tubing and piping. However, there is one additional problem—vehicles using LP gas must be serviced, like other vehicles, by filling stations and auto garages.



Safely arranged and constructed cylinder filling room. Cylinders are filled by weight with automatic shutoff valves. Room has explosion proof electrical fixtures and a fire extinguisher close at hand.

It is a common practice to bring motor vehicles inside garages for repair, servicing or storage. Unless the garage operator is familiar with LP gas, he may not pay much attention to the fuel used. Even if he recognizes the fuel as a possible hazard, he may decide to take a chance. These mistakes can be dangerous, as evidenced by many implement dealer and auto garages destroyed by explosion and fire.

Some typical examples are the following:

In Illinois, an implement dealer was servicing a new LP gas-fueled tractor inside the building. In servicing the unit, a connection was stripped on the fuel line and the shutoff valve on the tank had not been closed. Soon escaping gas was ignited by an unknown source (not too hard to find in a garage) and an explosion resulted, destroying the building and injuring five men.

Another case occurred in Minnesota, where an implement dealer left an LP gas-fueled tractor in his garage overnight. During the night a terrific explosion occurred, completely demolishing the implement dealer's building and causing damage to buildings more than a block away.

In Oklahoma, an auto garage dealer brought an LP gas tank truck into his garage for minor generator repair. The same story again: released gas resulted in an explosion, completely destroying the garage.

These accidents bring out the necessity for strict safety precautions in connection with servicing, repairing or storing LP gas vehicles, particularly inside of buildings.

LP gas-fueled industrial lift trucks are becoming quite popular. They present no additional hazard if the proper precautions are exercised. They also have the additional advantage of producing less carbon monoxide than gasoline units.

In a study on the carbon monoxide hazard from indoor use of propane-fueled industrial lift trucks,[7] it was found that propane-fueled units produced much less carbon monoxide than gasoline units. A well adjusted propane-fueled truck can be used for many operations where gasoline-powered trucks have proved hazardous.

Some safety precautions that should be followed in storing, repairing and servicing LP gas-fueled vehicles are the following:

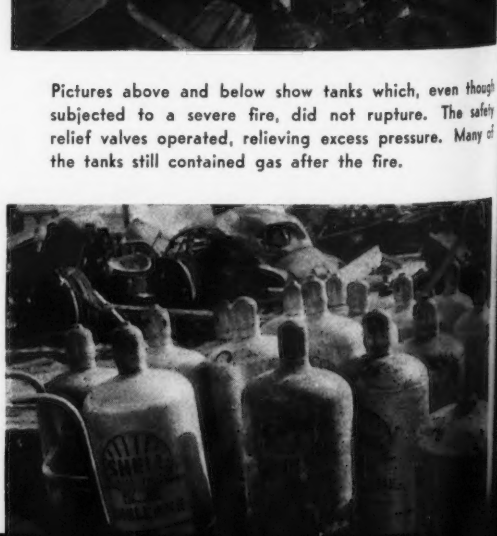
1. Preferably, vehicles using LP gas as a motor fuel should be serviced and repaired outside of buildings. However, if it is necessary to bring the vehicle inside, the LP gas liquid level in the tank should be checked to see that it is not overfilled and all shutoff valves should be closed.
2. LP gas-fueled vehicles should not be stored in buildings unless the building is specifically designed for such storage, with special ventilation.
3. All filling of LP gas-fueled vehicles should be done outdoors.
4. All employes must be taught the characteristics of LP gas and to handle it safely.

Safety Training for Employes

One of the favorite expressions used in discussing LP gas safety is that an employe should be a trained or qualified person. Such a statement takes in a lot of territory.

While there are some people who will perform unsafe acts even after they have received considerable training, we can, by requiring a minimum amount of training, at least be reasonably sure that a person will not perform an unsafe act through lack of knowledge.

It is highly desirable that all persons handling LP gas attend one of the schools regularly conducted by LP gas suppliers. These usually are excellent. They give the individual a good background in LP gas safety, covering such subjects as properties and characteristics of LP gas, transfer of LP gas, transportation, installation and adjustment of LP appliances, principles of operation of LP equipment, etc.



Pictures above and below show tanks which, even though subjected to a severe fire, did not rupture. The safety relief valves operated, relieving excess pressure. Many of the tanks still contained gas after the fire.

In addition, the individual should be thoroughly familiar with the National Fire Protection Association Pamphlet No. 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases.*[15] Preferably, he should be given a test on Pamphlet 58 to see whether he has grasped the information it presents.

Every new employe should work with an experienced employe for a time—long enough for the new man to grasp practical operation before he is allowed to work alone with LP gas.

A great many of the accidents which have occurred have resulted from lack of knowledge and training on the part of the person involved.

Fire Control in Emergencies

Many LP gas fires can be controlled in the early stages by appropriate fire extinguishers. All locations where LP gas is stored, handled or used should have an ample supply of fire extinguishers. This is particularly important on LP gas delivery trucks. Whenever a connection is broken, a little gas escapes and this may become ignited. Dry chemical or carbon dioxide are the most suitable extinguishers for LP gas fires. Extingusihers should be refilled every time they are used and should be checked regularly.

Wherever LP gas is used or stored in quantities, the local Fire Department should be advised and plans should be made with them to control a fire if it should occur. Special care must be exercised in extinguishing an LP gas fire so that, after extinguishment, the flow of gas can be stopped. If the gas flow cannot be stopped, it may be better to let the gas burn at the leak and keep it from spreading; if the flame is extinguished and the gas continues to leak, it may flow to an ignition source and a serious explosion could occur.

For example, suppose the safety relief valve is operating and the gas is burning at the valve because of overfilling and an increase in temperature. It probably would be preferable to cool the tank with a water hose stream, thus reducing the pressure and allowing the safety relief valve to close, cutting off the supply of gas. Excess liquid in the tank could then be pumped out.

It is difficult to say just what action should be taken in advance for any given emergency. Each situation has to be handled by quick thinking and good judgment. The following are suggested measures for controlling an emergency. However, other action may be indicated by the specific circumstances.

Leaks: Stop the flow of gas by closing all control valves. This should be done with extreme caution; otherwise, escaping gas may reach a source of ignition and flash back.

If leakage persists, warn all persons in the area involved and call the Fire Department.

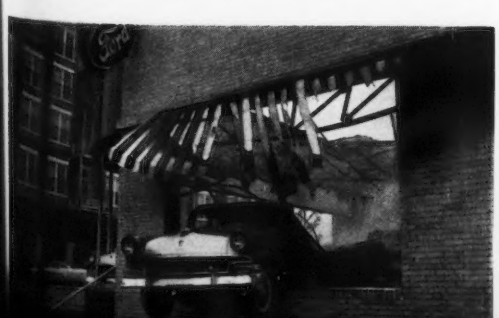
If wind direction tends to blow leaking gas toward buildings, evacuate all persons and turn off all pilot lights and electricity in these buildings.

Fires: Call the Fire Department—immediately.

Control flame spread with extinguishers. Do not put out LP gas flames unless you can shut off the tank's control valve. Extinguishment without shut-off permits gas to accumulate and may precipitate an explosion.

Use water hose lines to cool LP gas tanks. This reduces their internal pressure and minimizes the safety relief valve operation which adds gas to fire.

On below freezing day, LP gas tank truck, filled beyond permissible level, came into auto garage for minor repair. Warmer inside temperature caused gas to expand, release pressure relief valve. Escaping gas reached suspended gas heater; explosion occurred, fire followed.



Standards and Codes

There are a number of very fine standards and codes pertaining to LP gas. The principal standard for LP gas is the previously mentioned NFPA Pamphlet No. 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases.*[15] Many states have adopted this standard as their code for safety in storing and handling LP gas.

In addition, the following standards and codes apply to LP gas:

NFPA Pamphlet No. 52, *Liquefied Petroleum Gas Piping and Appliance Installations in Buildings.*[11]

NFPA Pamphlet No. 59, *LP Gas in Utility Gas Plants.*[12]

API-ASME *Code for Unfired Pressure Vessels for Petroleum Liquids and Gases*[3] or, "Rules for Construction of Unfired Pressure Vessels," Section VIII, *ASME Boiler and Pressure Vessel Code*.[14]

Regulations of the U. S. Interstate Commerce Commission outline specifications for transportation of explosives and dangerous articles *(Federal Code of Regulations,* Title 49, Parts 71-90).[16]

In addition, Underwriters' Laboratories Inc. and the American Gas Association Laboratories test and list LP gas equipment and appliances.[4, 5]

Conclusions

LP gas can be safely handled, stored and used. Past experience has proved this fact. However, those dealing with it should not become overconfident or lax.

Safety in handling LP gas is principally a job of educating and maintaining the interest of those who work with it.

Because of the catastrophic possibilities from an accident with LP gas, there is no margin for error. The first accident very well may be the last accident for the individual involved and others.

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15. *Standard for the Storage and Handling of Liquefied Petroleum Gases,* Pamphlet No. 58 (Boston: National Fire Protection Association, 1957).

16. "Transportation," Title 49, Parts 71-90, *Federal Code of Regulations.* Interstate Commerce Commission regulations for transportation of explosives and other dangerous articles (Washington, D. C.: U. S. Government Printing Office, 1956).

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Picture at left illustrates tremendous hazard associated with LP gas when it is not confined. In this city LP was used as utility gas and piped as air-gas mixture in underground mains. Corroded underground pipe leaked gas into basement of store. When electric light switch was turned on, explosion occurred, demolishing building and completely engulfing it in flame in about five minutes. Such explosions emphasize importance of safe piping of LP gas. Underground storage and piping always should be suspected because it is not possible to observe corrosive action and injury to pipe and tanks.

The Need for a THEORETICAL FRAMEWORK *in the Study of Accidents*

by Thomas H. Rockwell, Ph. D.

REVIEW of the research efforts in the field of industrial safety reveals two significant aspects. First, since the turn of the century, the understanding of the accident phenomenon has advanced only slightly, leaving us with a twentieth century problem of vast importance to be combated by nineteenth century knowledge. The position in this field is evidenced by an almost total lack of basic research aimed at a better understanding of the mechanism behind accidents. The causal philosophy behind accident prevention today is almost identical to that held by the pioneer men in the safety movement some 50 years ago. The same declarations made in 1900—of inadequate knowledge to attack the accident problem effectively—are voiced today by the foremost authorities.[4]

The second aspect is the lack of a unified research effort in dealing with the accident problem, as indicated by the specialized research efforts which have been and are being carried out in the various fields of study pertaining to safety work. Psychologists, sociologists, industrial physicians, engineers and safety practitioners often approach the same problem under different premises, resulting in contradictory or incomplete conclusions. An example of this would be the various views which have been expressed on the accident prone theory. And we cannot truthfully say that we understand the home or motor vehicle accident problem any better than the industrial one.

Our thinking on the subject of accidents still reflects the causal deterministic philosophy of the 1900's. To be sure, there have been some advancements. "Acts of God" virtually have been eliminated as a meaningful cause of accidents and have been replaced by more realistic thinking: that accidents are the result of our present technology outstripping man's ability to control it.

Use Trial and Error Approach

However, accident preventionists still are using a trial and error approach. Accidents are assigned causes which serve as the basis for preventive effort. Carelessness and blame still are often associated with accident causes. But assigning blame for an accident does not help prescribe the solution. And carelessness, like fatigue, is a descriptive term and cannot of itself cause anything; nor does such information assist us in preventing accidents.

Safety programs sometimes are dictated by mass statistics published by the National Safety Council and the Bureau of Labor Statistics. These statistics are basically for insurance and propaganda purposes and usually cannot provide an individual plant with information on which to justify an accident prevention program. The universally accepted accident frequency rate is not necessarily a true indicator of the

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In the many areas of industrial and public activity with which the safety field is concerned, almost all research projects, however worthwhile, have been undertaken to find immediate answers to immediate problems. A primary need in safety is major research effort on the basic causes of accidents, says Author Rockwell.

Need for a Framework *Continued*

safety level of a plant, since an accident is a consequence of worker behavior and the risk level of the operations performed. If chance is a factor in accident occurrence, then accident frequency is not necessarily a valid measure of safe operation since, under identical plant conditions and operator behavior, the observed accident frequency might vary considerably. What is conspicuous in the field of safety is the absence of any measurement theory and its attendant scale for comparison. Can we add unsafe acts or accidents and draw meaningful conclusions?

Let us assume that the basic elements of an accident are:

1. The environmental state of a task with its attendant risk.
2. Operator behavior in response to task stimuli, including his risk acceptance.

Lack Full Knowledge on Basic Points

If we assume further that the state of the environment and the state of operator behavior change over a period of time, resulting in some unpredicted instances in a combination of conditions which result in injury to the operator and/or damage to equipment and disruption of production, then several fundamental questions arise:

1. How are operator behavior and his environmental state interrelated?
2. Safetywise, what degree of control over his environment does the operator have or could be expected to have?
3. How does one measure the extent of risky behavior on the part of the operator?
4. If operator behavior is influenced by other accidents, safety programs, etc., how long does this effect last?
5. How does one measure the hazard level of a job or the "unsafeness" of an act?
6. What constitutes a job hazard in light of the operator's ability to change environmental states?
7. How can we separate accidents of omission from those of commission?
8. What is the nature of risk acceptance and what methods can be used to reduce the magnitude of an operator's risk acceptance?
9. How does an operator *learn* to be safe?

10. How does the probability of an accident increase with exposure to an unsafe environment or with continued unsafe behavior?
11. What are the temporal aspects of the accident situation?
12. What are the effects of stress, monotony and fatigue on safe operator behavior?
13. How does equipment design affect safe performance?
14. What are the roles of the psychologist, sociologist, engineer and physician in the prevention of accidents and what are the boundaries of their respective domains?
15. What is the relation between "no injury" accidents and traumatic accidents and how does one measure the former?

Although answers might be proffered to some of the above questions, at present there are no really satisfactory solutions to the problems posed by these questions. These problems are not theoretical ones which are of only academic interest. They are real deficiencies in our understanding of the accident phenomenon. Before we can tackle the accident problem efficiently, we first must acquire a firm theoretical foundation on which to base our efforts. The above questions point to a very definite need for basic research on the accident phenomenon to provide a framework within which our present knowledge can be explored and built upon.

It is not difficult to find the reasons for the lack of basic research to provide answers to these challenging problems. But while the reasons may explain, they certainly do not excuse our shortcomings. We must understand how the safety movement has reached its present predicament, so that ways of altering this situation can be suggested.

A look at the historical development of the safety movement in this country reveals that the house of safety was built on the sands of trial and error rather than on a foundation of the physical and behavioral sciences. From the early days—and it still persists today—the attitude has been that the qualifications of a good safety man are a winning personality and common sense. Although one cannot argue against such attributes, they hardly are adequate weapons, in themselves, to combat the complexity of the accident problems of today.

Work Only on Immediate Problems

One of the chief reasons for the lack of basic research is explained by the nature in which research in safety is initiated. As a rule, the emphasis is upon applied research; i.e., research directed toward a specific safety problem. As the frequency of punch press accidents increases, for instance, management will become alarmed and direct that a specific study be made to minimize this type of accident. Quite understandably, those industries in a position to sponsor research usually are primarily interested in getting answers to their own specific safety problems, rather than in supporting research of a basic nature.

The National Safety Council and the American Society of Safety Engineers, organizations in a position to encourage basic research, generally have followed the pattern of seeking immediate answers to immediate problems. Consequently, one finds research on safety belts and harnesses, eye protection and safety codes, instead of basic research.

As a result of the emphasis on applied research, much of the better research in the past 30 years has been directed toward areas which offer immediate payoff. Research on automobile accidents and accident proneness are examples of this. The controversial nature of accident proneness has encouraged spirited research efforts by physicians, mathematicians and psychologists. While this type of research extends our knowledge of the problem and in many cases represents a real, fundamental contribution, its basis is primarily empirical and is spelled out in terms of the implied causal model* of the accident. Moreover, we might question the success of such research in view of the continued staggering accident statistics reported each year.

There are many aspects of safety that are in need of research. Research is needed on the determination of the optimum direction and level of effort in safety programs. A formal concept of machine guarding, one that protects the operator and is not a bar to incentive, is a problem area which still offers potential. Research is vitally needed in employe selection methods so that workers can be placed most appropriately in industry. We should know much more about occupational deafness; realistic noise tolerance levels are required, as well, as a guide for noise control and abatement. We have a serious lack of information on the bodily effects of ionizing radiation and the control and treatment of exposure to such radiation. We must add to our knowledge on the general problem of dermatoses; although minor in severity, this disease represents approximately 50 per cent of all occupational disease claims. We need a continual reexamination of safety codes and regulations to keep pace with modern developments.

These are just a few potential problem areas that compete with fundamental research. In most cases, however, these problem areas could be studied more effectively if we had a better overall understanding of the accident phenomenon.

* *A* casual model *might be defined as the description of the accident phenomenon in terms of cause and effect.*

Need Coordination of Many Fields

Another reason for our predicament is the fact that many people in a position to support research oversimplify the problem. Some hold that discipline is *the* answer to the problem. Others insist education is *the* answer. Short range results from the use of safety propaganda are apt to convince a safety engineer that he has a clear cut solution to his safety problems. Moreover, the popular slogan, "Accidents Can Be Prevented," encourages those in safety simply to find and eliminate the recognized causes of accidents without looking deeper into the accident picture. This attitude certainly is not conducive to basic research.

A cogent difficuty in the advance of basic knowledge on accidents is the fact that most past research efforts have been confined within a single discipline, such as engineering, medicine or psychology. Yet, most would agree that safety cuts across several established disciplines. It is not only impractical but also impossible to compartmentalize accident prevention research. Accidents have so many ramifications that, to combat the problem properly, one must have access to psychological, sociological, medical and engineering knowledge.

To establish a theoretical foundation for the study of accidents, a concerted effort by these disciplines is necessary, not as in the past by several independent studies, but by an interdisciplinary approach where the many facets of the problem can be explored. Recent developments—in team research on systems problems in operations research—offer considerable potential in the field of safety research.

Must Promote Basic Research

The initial step in remedying the present safety enigma is to promote the realization that basic research is vitally needed to:

1. Serve as a basis for relating the many facets of the safety problem.
2. Provide a better understanding of the accident phenomenon so that subsequent applied research and accident prevention methods will be maximally effective.

What is required in this initial research is investigation into formal models of the accident phenomenon which describe in precise language the interrelation of operator behavior, environment and accidents. This requires extensive research effort in formal model investigation and construction.

Coincident to this formal development should be a method to establish accurately what present problems in accident prevention exist today. The critical incidence approach used by Fitts and Jones,[2] offers an important contribution to the definition of the safety problem areas and the conditions under which they have developed. Some of the formal models which offer potential in basic research include game theoretic, probabilistic, information theory and servomechanism models.[3] This will require the establishment of an interdisciplinary team of research workers to assist in building a framework for accident prevention and to carry out research to answer problems suggested by the model. The conspicuous absence of such team research in the past is responsible, in part, for the lack of unity in present industrial safety methodology.

The task is indeed a herculean one, since what we are asking for, essentially, is the prediction of human behavior. Although the behavioral sciences have yet to formalize human behavior completely, progress has been made along these lines; for example, stochastic learning models.[1] The orientation of these formal developments around safety considerations would be a logical starting point in this research. The growing importance of the accident problem demands an understanding of the accident phenomenon to build prevention techniques.

One answer to the predicament in safety research is adequate financial support. This writer's experience has indicated that capable interdisciplinary teams do exist, as well as the ideas necessary to initiate research. The primary difficulty has been the lack of funds necessary to set the research in motion. If the safety problem were to be attacked with the basic approach and the vigorous financial support offered to cancer or polio research, it is less likely that, in the future, we would be facing the theoretical drought that exists today.

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THE American Society of Safety Engineers has established the following classifications of active membership.

MEMBER — To be eligible as a Member an applicant shall be at least thirty years of age and shall be engaged in safety engineering. In addition, he shall have either an engineering or science degree in an accredited college curriculum and the equivalent of eight full years' experience in safety engineering; or he shall have had the equivalent of ten full years' experience in safety engineering.

ASSOCIATE MEMBER — To be eligible as an Associate Member an applicant shall be at least twenty-five years of age and shall be engaged in safety engineering. In addition, he shall have either an engineering or science degree in an accredited college curriculum and the equivalent of three full years' experience in safety engineering; or he shall have the equivalent of five full years' experience in safety engineering; or he shall have either an engineering or science degree in an accredited college curriculum, ten years' experience in professional engineering work and one full year's experience in safety engineering; or he shall have twenty years' experience in engineering work, of which at least ten have been at the professional level, and one full year's experience in safety engineering.

JUNIOR MEMBER — To be eligible as a Junior Member an applicant shall be at least twenty years of age and shall be engaged in safety engineering work, which if pursued the required time will tend to qualify the applicant for the classification of Associate Member. In addition, he shall have either an engineering or science degree in an accredited college curriculum or he shall have had the equivalent of one full year's experience in safety engineering.

AFFILIATE MEMBER — The Society also provides a special classification, that of Affiliate Member, for those not professionally engaged in safety engineering. To be eligible as an Affiliate Member an applicant shall be at least twenty-five years of age and shall have contributed to the advancement of safety engineering through demonstrated achievement in some related field of interest in which he has been engaged for at least three years.

for additional information write to

The American Society of Safety Engineers
425 North Michigan Avenue
Chicago 11, Illinois
(or contact your local chapter)

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